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Case Study

Accumulation of Pollutants in an Ultisol amended with burnt and unburnt rice miled wastes.

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An experiment was conducted in 2008 and 2009 cropping seasons and a residual trail in 2010 cropping season to evaluate the effects of two rates (10 t ha-^{1} and 20 t ha-^{1}) each of burnt, unburnt and mixtures of burnt + unburnt rice mill wastes on content of heavy metals (cu,zn,pb), So_4^{2}-, No_3-, exchangeable sodium percent (EPP%), exchangeable potassium percent (EPP%) and sodium adsorption ratio (SAR) of an ultisol in south eastern Nigeria. A control (C) was also included. Results of the study showed significantly (P ≤ 0.05) higher values zn, cu, pb, SO_4^{2-}, NO_3^- and lower values of SAR, EPP% and ESP% in waste amended plots relative to the control in the three cropping seasons. Increasing the rates of the amendments was observed to increase SO_4^{2-}, NO_3^- and heavy metal (zn,cu,pb) content but lowers SAR, EPP% and ESP% values .Observed values of zn,cu, pb, SO_4^{2-}, NO_3^-, EPP%, ESP% and SAR in waste amended plots in the three cropping seasons were within acceptable limits in soil. Unburnt and burnt rice mill waste at the rates studied did not constitute pollution problem when used as soil amendment.

Keywords: pollution problem, amendments, acceptable limits, cropping seasons, rice mill waste

Introduction

Many tropical soils have low organic matter (OM). Consequently some physicochemical characteristics of such soils are not at optimum levels for high and sustained productivity (Mbagwu, 1989). Thus, farmers in the tropics face the problems of maintaining soil productivity, with soil infertility according to Mbah and Mbagwu (2006) being a major over-riding constraint that affect all aspects of crop production. The decline in soil fertility is aggravated by the spate of degradation resulting from natural as well as human factors. Donova and Casey (1998) reported that decline in soil fertility may occur through leaching, soil erosion and crop harvesting. According to Federal ministry of Agriculture and Natural Resources Management (1990) intensified food crop production and over use of soil with out appropriate maintenance has led to reduced soil fertility and consequently decline in the productivity of soils. Unless the nutrients are replenished through the use of organic or mineral fertilizer, or partially through crop residue or rebuilt more comprehensively through traditional fallow system, that allow restoration of nutrients and reconstitution of soil organic matter, soil nutrient level will decline continuously Kesseba (1995). Bumb (1994) and Gardner *et al.* (1995) observed that although the use of mineral fertilizer is the convenient way for rapid correction of nutrient deficiencies in soils, its scarcity and high cost limits its wide application by farmers.

Consequently alternative food production systems that could build up organic matter and improve soil physical and chemical properties for sustained production at affordable cost are being developed. One of this is the use of organic amendments or wastes. Of the various wastes studied animal droppings, green manure and compost manures have been receiving research attention (Okonkwo and Ogu, 2002). According to Shima *et al.*, (2010) land application of organic amendments like sewage sludge, municipal solid compost and animal manure is an excellent way of recycling both the nutrients and the OM contained in them. The importance of OM from wastes in relation to the physical fertility of soil has been widely recognized (Barzegar *et al.,* 1996).Burnt and unburnt rice mill wastes have received far less attention.

In Abakaliki south eastern Nigeria large quantities of burnt and unburnt rice mill wastes accumulate from the numerous rice milling industries. These wastes have formed artificial mountains and are occupying a considerable portion of arable land in that agro-ecological zone. Anikwe (2000) observed that rice mill wastes have high specific surface area and high OM content and recommend its use as soil amendment for improved crop production. Nnabude and Mbagwu (2001) reported significant reduction in soil bulk density as well as improvements in water stable aggregates, total porosity, C, N, and BS when they used burnt and unburnt rice mill wastes as soil amendments. However, little or no attention has been given to pollution potentials (interms of contents of heavy metals ,sulphate (SO_4^{2}), nitrate (No_3-), exchangeable potassium percent (EPP%), exchangeable sodium percent(EPP%) and sodium adsorption ratio (SAR) of rice mill waste as soil amendment. The objective of this study was to evaluate the pollution potentials in-terms of soil contents of heavy metals, (zn, pb and cu) sulphate (So_4^{2-}), Nitrate (NO_3^-), exchangeable potassium percent (EPP),sodium adsorption ratio (SAR), exchangeable sodium percent (EPP) of burnt and unburnt rice mill wastes as soil amendment.

Material and Methods

Methods:

The experiment was carried out at Teaching and Research Farm of faculty of Agriculture and Natural Resources Management Ebonyi State University, Abakaliki during the 2008, 2009 and 2010 cropping seasons. The area is located at latitude 6°19[1]N and longitude 8° 06[1]E in the derived savannah of the south east agro-ecological zone of Nigeria. The area has an annual rain fall of 1700 – 1800 mm. The rainfall pattern is bimodal between April – July and September – November with short spell in August. The Area has a relative humidity of between 60 -80% and a minimum and maximum temperature of 27°C and 31°C, respectively (Ofomata, 1975). The Soil belongs to the order ultisol and classified as Typic Haplustult (Federal Department of Agriculture and Land Resources,1985)).

A land area measuring 24 m x 14 m was mapped out and used for the study. The experiment was laid out as a randomized complete block design with 21 plots each measuring 3m x 4m. Plots were separated by 0.5m alley and each replicate was 1m apart. The expermental site was cleared of the natural vegetation (*Imperata cyclindrica, panicum maximum* and *odoratum Spp*) in 2008 cropping season. The debris was removed and the area cultivated using hoe. The treatments were uniformly spread and buried in their respective plots immediately after cultivation. The treatments were;

(i) O – Control
(ii) BW_{10} – 12kg/plot burnt rice mill waste equivalent to 10 t ha^{-1}
(iii) BW_{20} -24kg/plot unburnt rice mill waste equivalent to 20 t ha^{-1}
(iv) UW_{10}- 12kg/plot burnt rice mill waste equivalent to 10 t ha^{-1}
(v) UW_{20}- 24kg/plot unburnt rice mill waste equivalent to 20 t ha^{-1}
(vi) BUW_{10} - 6kg BW +6kg UW / plot equivalent to 10 t ha^{-1}
(vii) BUW_{20} – 12 kg BW+12 kgUW/ plot equivalent to 20 t ha^{-1}

Two maize seeds per hole were planted at a spacing of 25cm with row and 75cm between rows at a depth of 3cm. The experimental site was weeded at three weeks interval. The same procedure was repeated in 2009 and 2010 cropping seasons but without application of amendments in 2010 cropping seasons to test the residual effects of the rates of the wastes.

Four auger samples each were collected from the study site at the initiation of the study and two auger samples from each plot at the end of the study (90 days after harvest of maize) in each cropping season for laboratory analysis.

Soil suphate (SO_4^{2-}) and $N0_3^-$ contents were determined using turbidimetric method (Tabatabai, 1974) and the method of O'Dell (1993), respectively. Exchangeable bases were determined by the method of Chapman (1982). The complexiometric titration method was used to determine Ca and Mg while Na and k were determined from IN ammonium acetate (NH_4OAC) using flame photometer. Exchangeable sodium percent (ESP%),sodium adsorption ratio (SAR) and Exchangeable potassium percent (EPP%) were calculated using the method of Richards (1954) as follows.

$$ESP = Na^+/CEC \times \frac{100}{1} \quad \text{---------------------------1}$$

$$SAR = Na^+/[Ca^{2+} + Mg^{2+}/2)]^{1/2} \quad \text{---------------------------2}$$

$$EPP = K^+/CEC \times \frac{100}{1} \quad \text{---------------------------3}$$

Where;
ESP= Exchangeable sodium percent, SAR= sodium adsorption ratio, Epp= Exchangeable potassium percent, CEC= cation exchange capacity.

Contents of heavy metals (cu, fe and zn) were determined using atomic absorption spectrophotometer after digestion with concentrated HNO_3^- (Clayton and Tiller, 1979).

DATA ANALYSIS

Statistical analysis of collected data was conducted using the general linear model of SAS software for Randomized complete block design (SAS, Institute Inc., 1999). The means were separated using Duncan multiple range test.

RESULTS

Table 1 show that the control plots consistently had higher values of SAR, ESP % and EPP% relative to rice mill waste amended plots in the three cropping seasons. The table also showed that increasing the rates of rice mill waste (Burnt, unburnt and mixture of burnt and unburnt) decreased ESP%, EPP% and SAR across the two seasons of waste application. Observed values of SAR, ESP% and ESP% ranged between 0.07 – 0.12, 1.90 – 2.35% and 2.02 – 2.73% respectively in 2008 cropping season.

Table 1. Effect of burnt and unburnt rice mill wastes on soil ESP (%) EPP (%) and SAR

Treatment	2008			2009			2010		
	ESP	EPP	SAR	ESP	EPP	SAR	ESP	EPP	SAR
C	5.26^{a}	2.63^{a}	0.16^{a}	5.09^{a}	2.32^{a}	0.16^{a}	8.70^{a}	4.35^{a}	0.30^{a}
BW10	$2.59b^{c}$	1.97^{de}	0.10^{cd}	4.17^{b}	1.83^{c}	0.13^{b}	0.03^{b}	3.65^{b}	0.29^{g}
BW20	2.02^{e}	1.86^{e}	0.07^{ef}	3.29^{de}	1.83^{c}	0.11^{c}	6.36^{d}	2.73^{d}	0.20^{b}
UW10	2.73^{b}	2.35^{b}	0.12^{b}	4.03^{b}	2.01^{b}	0.13^{b}	6.45^{d}	3.32^{c}	0.22^{b}
UW20	2.31^{d}	2.03^{cd}	0.05^{f}	3.68^{c}	1.84^{c}	0.11^{c}	6.63^{cd}	2.78^{d}	0.15^{c}
BUW10	2.49^{bd}	2.17^{c}	0.10^{cd}	3.10^{e}	1.67^{d}	0.09^{d}	4.02^{f}	3.76^{b}	0.20^{b}
BUW20	2.36^{cd}	$1.90d^{e}$	$0.9d^{e}$	3.37^{d}	1.58^{d}	0.10^{c}	6.74^{c}	3.37^{c}	0.22^{b}

Means on the same Column with the same letter do not differ significantly (P = 0.05)

C = control, BW_{10} = burnt rice mill waste at 10tha^{-1},BW_{20} = burnt rice mill waste at 20 t ha^{-1},UW_{10} = unburnt rice mill waste at 10 t ha^{-1},UW_{20} = unburnt rice mill waste at 20 t ha^{-1},BUW_{10} = 5 t ha^{-1} BW_{10} and 5t ha^{-1} UW_{10},BUW_{20} = 10 t ha^{-1} BW and 10 t ha^{-1} $UW_{20.}$

In 2009 cropping season application of amendments reduced ESP% by 18%, 35%, 21%, 28%, 29% and 34% relative to the control for BW_{10}, BW_{20}, UW_{10}, UW_{20}, BUW_{10} and BUW_{20} respectively. Higher values of ESP and SAR were observed in 2009 cropping season relative to 2008 cropping season. The table also showed that application of the burnt and unburnt rice mill waste in 2009 cropping season reduced EPP relative to EPP values in 2008.

Similarly, significant reduction in SAR, EPP%, and ESP% were recorded in waste amended plots in the residual (2010) cropping season relative to the control. In this season ESP%, EPP% and SAR ranged between 4.63 – 8.03, 2.73 – 3.76 and 0.15 – 0.29, respectively in rice mill waste amended plots.

As shown in table 2 changes in soil contents of $S0_4^{2-}$ and $N0_3^{-}$ of waste amended plots were significantly lower relative to the control at $P \leq 0.05$.

Table 2 . Effect of treatments on soil sulphate (SO_4^{2-}) and (nitrate) NO_3^{-}

	Cropping Seasons					
Treatments	2008		2009		2010	
	SO_4^{2-}	NO_3^{-}	SO_4^{2-}	$N0_3^{-}$	SO_4^{2-}	NO_3^{-}
C	8.25^{f}	0.03^{c}	7.63^{c}	0.02^{d}	3.62^{g}	0.01^{c}
Bw_{10}	10.02^{e}	0.04^{c}	8.99^{d}	0.05^{c}	4.99^{f}	0.02^{bc}
BW_{20}	11.43^{d}	0.04^{c}	9.16^{d}	0.05^{c}	6.58^{c}	0.04^{b}
UN_{10}	14.62^{a}	0.06^{b}	10.21^{c}	0.07^{b}	6.24^{d}	0.04^{b}
UN_{20}	15.08^{a}	0.08^{a}	12.06^{a}	0.09^{a}	9.37^{a}	0.07^{a}
BUW_{10}	12.9^{c}	0.06b	9.77^{c}	0.07^{b}	5.22^{e}	0.03^{bc}
BUW_{20}	13.86^{b}	0.07^{ab}	11.23^{b}	0.08^{ab}	7.37^{a}	0.04^{b}

Means on the same Column with the same letter do not differ significantly (P = 0.05)

C = control,BW_{10} = burnt rice mill waste at 10 t ha^{-1},BW_{20} = burnt rice mill waste at 20 t ha^{-1},UW_{10} = unburnt rice mill waste at 10 t ha^{-1},UW_{20} = unburnt rice mill waste at 20 t ha^{-1},BUW_{10} = 5 t ha^{-1} BW_{10} and 5 t ha^{-1} UW_{10},BUW_{20} = 10 t ha^{-1} BW and 10 t ha^{-1} UW_{20}

For example in 2008 burnt, unburnt and unburnt + burnt rice mill waste at all rates had higher values of SO_4^{2}- compared to the control. In 2009 cropping season 17%, 20%, 34%, 58%, 28% and 47% increase in SO_4^{2-} relative to the control was observed for BW_{10}, BW_{20}, UW_{10}, Uw_{20}, BUW_{10}, and BUW_{20} – amendments, respectively. Recorded value of $N0_3$- for the two seasons of application ranges between 8.25 – 14.6 and 0.03 – 0.08, respectively. The table also showed that increasing the rate of rice mill waste application increases the value of SO_4^{2-} and NO_3^{-}. The Table also showed that continuous application of wastes in 2009 cropping season decreased soil SO_4^{2-} and increased soil NO_3^{-} content. In the residual (2010) cropping season significantly ($P \leq 0.05$) higher values of No_3^{-} and SO_4^{2-} were observed in waste amended plots relative to the control. At the rate of 20 t ha^{-1} application of burnt, unburnt and mixture of burnt + unburnt wastes in the residual season increased soil SO_4^{2-} content by 82%, 159%, and 104%, respectively, relative to the control.

Difference in soil contents of cu, zn and pb following amendment with rice mill wastes is shown in table 3. In the two-cropping seasons of waste application, significantly ($P \leq 0.05$) higher values of cu, zn and pb were observed in rice mill waste amended plots relative to the control.

3: Effect of rice mill wastes on soil heavy metal (cu, zn ,pb) contents (Mgkg-1)

	2008			2009			2010		
Treatment	cu	zn	pb	cu	zn	pb	cu	zn	pb
C	7.04f	9.20c	2.32c	5.23f	6.12f	1.98d	4.23g	3.38f	1.36e
BW10	11.21d	10.36b	3.06b	10.27c	8.28c	2.76c	6.28e	5.63c	2.02d
BW20	18.16a	11.06a	4.21a	15.01a	9.64a	3.96a	10.68a	7.56a	2.96b
UW10	10.10e	10.15b	3.13b	8.23c	6.28f	3.01b	5.56f	5.23e	2.92b
UW20	12.25c	10.80a	4.26a	10.21c	7.66d	3.98a	7.71c	7.02b	3.06a
BUW10	10.14e	10.40b	3.09b	9.45d	7.20c	2.81c	6.61c	5.43d	2.34c
BUW20	15.36b	10.38b	4.23a	10.01b	8.98b	3.09b	9.85b	5.61c	3.01ab

Means on the same Column with the same letter do not differ significantly (P = 0.05) .

C = control,BW10 = burnt rice mill waste at 10 t ha-1,BW20 = burnt rice mill waste at 20 t ha-1,UW10 = unburnt rice mill waste at 10 t ha-1,UW20 = unburnt rice mill waste at 20 t ha-1,BUW10 = 5 t ha-1 BW10 and 5 t ha-1 UW10,BUW20 = 10 t ha-1 BW and 10 t ha-1 UW20.

The Table also showed that the effect of wastes on soil content of zn, pb and cu was waste dependent. Highest values of zn, pb and cu were observed in 20 t ha^{-1} of BW_{20} – amended plots in 2008 and 2009 cropping seasons. In 2009 cropping season the order of increase in soil contents of cu, zn and pb were $BW_{20} > BUW_{20} > BW_{10} > UW_{20} > BUW_{10} > UW_{10} >$C, $BW_{20} > BUW_{20} > BW_{10} > BUW_{10} > UW_{10} >$ C, and $UW_{20} > BW_{20} > BUW_{20} > UW_{10} > UW_{20} > BW_{10} >$C, respectively. However lower values of zn, cu and pb were recorded in rice mill waste amended plots in 2009 cropping season relative to the 2008 cropping season. Amendment of soil with BW_{20} recorded the highest values of cu and zn in the 2008 and 2009 cropping seasons while UW_{20} gave the highest value of pb in (2010) residual cropping season.

Discussions

Exchangeable sodium percent (ESP) and sodium adsorption ratio (SAR) are two parameters by which sodicity are evaluated. Mbah *et al.* (2005) observed that sodic soils exhibit poor – soil – waste – air relation which adversely affect water movement, root growth and make soil difficult to work leading to abandonment of the soil. According, to US Salinity Laboratory staff (1954) an ESP >15 adversely affects the physical properties of a soil. McNeal and Coleman (1966) used seven soils in Western United States and concluded that ESP 15 can separate sodic and non-sodic soils. Agasi *et al.* (1981) reported that infiltration rate depends on electrical conductivity (EC) and ESP but is more sensitive to increasing ESP than EC because the energy of impacting rain drops promotes dispersion allowing a seal to form at the surface (Oester and Shroer, 1979). High percent of exchangeable Na according to Stewart and Meek (1977) result in dispersed condition that restrict plant growth and water movement in swelling type clay. Results from this study (Table 1) show that application of unburnt, burnt and mixture of burnt + unburnt at the rates studied decreased soil contents of SAR and ESP, implying improved structure and permeability relative to the control in the studied soil.

Results of the study (Table 2) show significantly higher levels of NO_3^- and SO_4^{2-} in the rice mill waste amended plots relative to the control. In a study on the sodicity and sulphate content of an ultisol amended with animal wastes Mbah *et al.* (2005) observed increased levels of So_4^{2}- in animal waste amended plots relative to the control. The authors recommended that animal wastes application at rates of 10tha^{-1} and 20tha^{-1} should not be on continuous basis to avoid accumulation of SO_4^{2}- to toxic levels. The result of this study seem to suggest that the effect of wastes on soil SO_4^{2-} and NO_3^- is wastes dependent while continuous application of animal wastes raise soil SO_4^{2-} to toxic levels (Mbah *et al.*, 2005) continuous application of plant based wastes in this study raised soil SO_4^{2-} non-toxic levels in soil. Longe (1967) observed that SO_4^{2-} concentration above 250 mgL^{-1} in drinking water constitute potential danger to human beings. The recorded increment in soil SO_4^{2-} and NO_3^- following application of rice mill wastes in this study is within acceptable levels. Soil application of rice mill wastes significantly ($P \leq 0.05$) increased cu, zn and pb contents of the soil relative to the control (Table 3). This is inline with the observation of Purves (1977) who reported significant increase on the amount of cu, B and zn extractable from soil after compost application. Similar, result was reported by Mohr (1979) with respect to zn and cu. Similarly, Gallardo-lara *et al.* (1984) observed increased residual extractable zn following increased application of waste in line with the result of this study. Zinc (zn) and cu are toxic to plants before accumulation to affect animals and man, and over application of wastes tends to kill or stunt plants, preventing poisoning of animals. Alloway (1996) reported that the normal range of zn in soil is 1-900 $mgkg^{-1}$ while that of cu is 2 – 250 $mgkg^{-1}$. Lead (pb) is believed to be absorbed by soil and is highly insoluble. Smith (1996) reported that direct soil ingestion by children living in amended soil is the limiting pathway for pb. Brown (1977) observed that the normal range of pb in plants is 0.2 – 20 $mgkg^{-1}$ whereas Kabata – Pendias and Pendias (1984) showed that shoot content of pb within 30 – 300 $mgkg^{-1}$ cause toxicity in plants. Contamination of soil and subsequent uptake by plants and transfer to animal are major risk pathway for heavy metals. Results of this study showed that application of rice mill wastes at the rates studies increased zn, cu and pb content of the soil to non-toxic levels.

Conclusion

Results of this study show that application of rice mill wastes (burnt, unburnt and mixture of burnt +unburnt) could improve soil structure and permeability through reduction in SAR and ESP. Similarly, the use of rice mill wastes as soil amendments increases the soil contents of heavy metals (zn, cu, pb), SO_4^{2-} and NO_3^- to non-toxic levels. Thus, rice mill wastes at the rates studied could be used as soil amendment on continuous basis since it does not constitute pollution problem.

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